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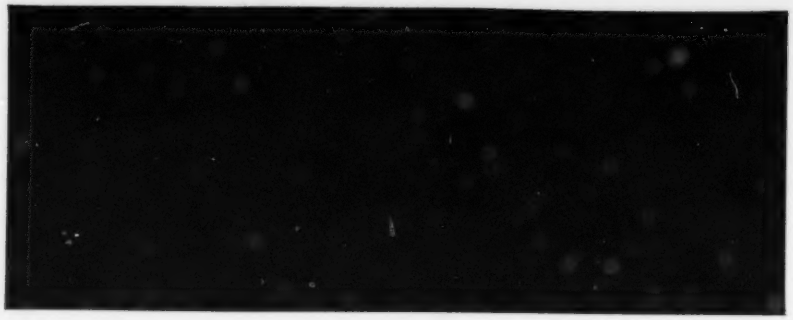

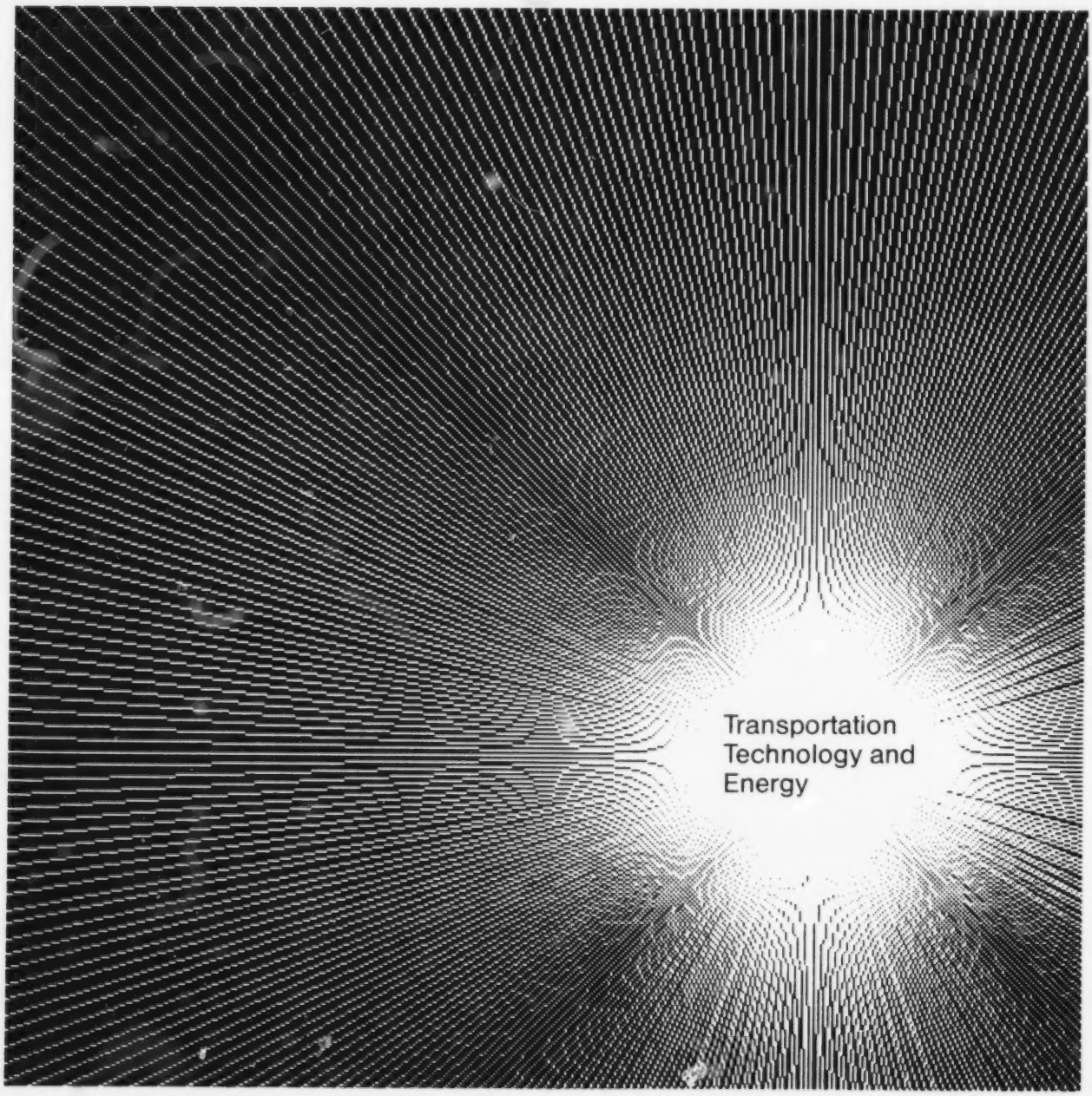

Trends in Electronic Vehicle Monitoring Technology (EVMT) Applications

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TRENDS IN ELECTRONIC VEHICLE MONITORING TECHNOLOGY (EVMT) APPLICATIONS

Tsai, J.

ABSTRACT

Applications of electronic systems to commercial and private passenger vehicles increase the productivity, and improve the safety of the vehicles. New electronic technologies such as mobile satellites, cellular radios, vehicle location and navigation, vehicle on-board microcomputers, artificial intelligence, automatic vehicle identification (AVI), automatic vehicle classification (AVC), and weigh-in-motion (WIM) have quickened the pace of technology applications in the transportation sector.

A new system, Ontario's wide area vehicle monitoring (WAVM), which utilizes satellite navigation and communications technologies, is being enthusiastically received by the trucking industry and is in the implementation stage. Many vehicle fleet management systems utilizing mobile radio and automatic vehicle location devices are now available for commercial application in urban areas. Computerized dashboard maps, coupled with a space-age navigation device and a voice alert system, have been tested and marketed by auto makers for the family car. Stand-alone vehicle electronic information systems are available to monitor tachometer, odometer, and engine performance. Computerized traffic control systems and electronic route guidance systems have been implemented and tested in many countries. Meanwhile, government agencies responsible for highway infrastructure operation and maintenance are interested in applying new technologies, in particular, AVI, AVC, and WIM, to develop more cost-effective approaches to the collection of heavy-vehicle data.

The transportation industry favours the use of EVMT to improve fleet management, vehicle dispatch, and vehicle productivity. Government agencies are interested in the use of such technology to collect vehicle data, streamline complex regulatory processes, enhance highway engineering and design work, and improve traffic flow. Will these diversified application trends converge to the satisfaction of all concerned?

This paper will review the current and emerging electronic vehicle monitoring technology applications, discuss the possible inter-relationship of various applications being contemplated, and describe an interface concept to integrate electronic vehicle monitoring systems for future application consideration.

INTRODUCTION

Since the first microprocessor application to passenger cars in 1977 [1], the number of electronically monitored and controlled vehicle functions for both commercial vehicles and private passenger automobiles has increased phenomenally. New electronic technologies such as mobile satellites, cellular radios, vehicle location and navigation, vehicle on-board microcomputers, artificial intelligence, automatic vehicle identification (AVI), automatic vehicle classification (AVC), weigh-in-motion (WIM), and wide area vehicle monitoring (WAVM) have quickened the pace of technology applications in the transportation sector.

CURRENT AND EMERGING ELECTRONIC VEHICLE MONITORING TECHNOLOGY APPLICATIONS

Electronic vehicle monitoring technology (EVMT) applications can be classified as those designed for the transportation industry and those designed for government regulatory agencies. EVMT applications in the transportation industry can be further divided into commercial vehicle and private passenger automobile categories. Figure 1 shows the EVMT application areas.

APPLICATIONS TO COMMERCIAL VEHICLES

Electronic Trip Recorder

One of the most popular EVMT application systems for commercial vehicles is the electronic trip recorder. There are many different brands of electronic trip recorders produced by several Canadian and American companies [2 to 7]. A typical electronic trip recorder receives data on road speed, engine rpm, and fuel consumption when it is connected to a vehicle's speed, rpm, and fuel sensors and its electrical system. The trip recorder is usually initialized with the vehicle's identity and calibrated for the vehicle's specified configuration. The trip recorder's monitoring intelligence is customized to individual fleet operating standards. With an electronic trip recorder, every second of vehicle operation, including stop time, is monitored and recorded. A new feature of the electronic trip recorder is that it automates the carrier's entire log-keeping process. This feature allows the driver to key his duty status, identification, and location into the computer when he starts work. From that moment until the driver logs off again at the end of his work cycle, duty status changes will be documented automatically. Based on the data collected by the electronic trip recorder, many useful analyses, such as trip, vehicle speed/rpm, vehicle and driver summary, driver performance, and fuel usage analysis reports, can be generated for productivity improvement.

Speed Control, Weight Control, and Artificial Intelligence

Other commercial vehicle EVMT applications include truck speed and engine control [8,9], a self-weighing system with sensors placed on the vehicle axle to measure the load, and an on-board microcomputer that provides readouts of gross vehicle payload as well as individual axle loads [10], transmission control [11], and diagnostics [12]. In the future, the computerization of heavy trucks [13] will improve vehicle safety, comfort, and efficiency.

In addition to these features, other devices under development include alertness and uncooled engine sensors, nationwide voice and data communications via satellite, and radar to prevent collisions, to name a few.

An artificial intelligence vehicle or autonomous land vehicle (ALV) is being developed by the US government. An ALV is an unmanned vehicle which will travel down a road or over open terrain on its own. This requires a vision capability to sense and classify landmarks, geographic features, and obstacles, as well as artificial intelligence to reason using incomplete information.

Fleet Dispatching and Routing

For fleet dispatching and routing applications, there are many computerized systems available from several Canadian and US companies [14 to 18]. A typical computerized dispatch system stores customer, truck fleet, and driver data bases. Using customers' current demands and stored data base information, the computerized dispatch system will assist the dispatcher to match shipping requirements with available trucks and drivers. Some systems will also provide alternative routes. One problem that long-haul and regional operators must cope with, which is associated with this application of EVMT, is the loss of contact with each truck between the time it is dispatched and the time the driver calls back.

Fleet Tracking and Vehicle Location

For vehicle positioning and fleet tracking applications within limited areas, several Canadian and American companies offer systems [19 to 27] which utilize high resolution map displays to locate vehicles at a glance. The system can interpret vehicle location data, usually from a Loran-C receiver, to pinpoint a vehicle's position on the map display. The map display capability can zoom from a continent-wide display down to the city street level. It can receive vehicle status and messages quickly and easily when a mobile communications facility is available. It can alert the dispatcher when a vehicle available for dispatch enters an area where a customer has goods ready to be shipped. A major limitation of this type

of system is that the current vehicle positioning and communications capability only covers major urban centres and some major corridor areas where land-based terrestrial radio navigation and communications infrastructures are in existence. Wide area coverage is not yet available. However, some of these systems such as Fleet-Trac [19] and Fleetview [20] are designed or can be adapted to utilize satellite-based navigation and communications facilities when they become available in 1988 or later.

Wide Area Vehicle Monitoring (WAVM)

In long-haul and regional trucking operations, two traditional problems trucking companies face are the inability to reach the drivers at will and the inability to locate the trucks when required. These problems exist because truck fleet operations cover a very wide geographical area and there is a lack of suitable vehicle positioning and communications technologies to serve the needs of the trucking industry. The WAVM system [28,29] is an application of satellite navigation and communications technologies. Utilizing the communications infrastructure provided by the Mobile Satellite and the vehicle positioning capability provided by the navigation satellites -- Global Positioning System (GPS), or Loran-C land-based vehicle navigation system -- the WAVM system will be capable of operating from coast to coast in North America. The system will provide real-time truck location and identification information, and two-way message communication between equipped trucks and trucking company base stations. Many trucking companies consider the WAVM system an important link currently missing between their computerized fleet dispatch systems and their trucks on the road. In addition, other EVMT devices such as the electronic trip recorder, speed control, weight control, etc., could be integrated with the WAVM system, and vehicle status information could be transmitted back to the truck fleet base station for management action. The application of WAVM system technology will bring major changes and improvements to truck dispatching and management philosophies. Figure 2 shows the WAVM system configuration.

Recognizing the potential of the WAVM system technology and working in co-operation with two trucking companies, the Ministry of Transportation has organized a project group to facilitate WAVM system applications in the truck fleet sector and to promote this new opportunity in the transportation market to high technology industries. The WAVM project group has evaluated various vehicle positioning and communications technologies for possible WAVM demonstration and has also defined the WAVM system operating requirements based on the participating trucking companies' needs and requirements. More recently, an interim WAVM demonstration scheme based on the existing satellite channels has been adopted by the project group, which includes trucking companies, high technology service and equipment suppliers, the federal Department of Communications (DOC), and the Ontario Ministry of Transportation.

WAVM system technology can also be adapted and utilized by bus, rail, marine, and air sectors.

APPLICATIONS TO PRIVATE PASSENGER AUTOMOBILES

There are many applications of EVMT to private passenger automobiles currently in use and being developed [30 to 37], such as computer-controlled fuel injection, electronic ignition control, and an on-board microcomputer. In the future, most cars will have multi-purpose video screens; drivers will use the displays for everything from pinpointing their location on a computer-generated map to plotting mileage. And the car's master computer, keeping a watchful eye on overall operations, will display friendly reminders, such as "it's time for an oil change," on the screen. Some recent advances in passenger car applications are summarized below.

Space-Age Navigation

The space-age navigation system employs radio signals from orbiting satellites to pinpoint a vehicle's location on a computerized map. Major automobile companies have developed such locator systems for use in cars. In Chrysler's system (called CLASS), the traditional glove compartment is replaced with a video display screen located under the dashboard. At the beginning of a trip, a map of the whole country, stored on a laser videodisc, appears on the screen. By touching the screen, the driver can zoom in on a particular part of the map. At the same time, the computerized system continuously calculates the location of the car from satellite (GPS) signals. The vehicle shows up as a symbol on the screen and moves across the map as the car travels. The computer can even display the best route to a destination. Ford and GM have systems similar to this, but theirs use videotape to store the map data.

Another development is a computerized dashboard map system, called ETAK Navigator, designed for passenger car use and available commercially. It utilizes a dead reckoning navigation technique, augmented by map correlation. The system allows drivers to glance at the electronic road map to see their current location and the location of their destination. As the driver drives, the vehicle's position on the screen remains constant, and the map moves accordingly. Streets going by outside the car window are simultaneously displayed on the screen, providing clear and consistent orientation. The device is especially useful when drivers are not familiar with a city street network.

Safety and Comfort Applications

One example of the coming attractions is Buick's Questor, in which the rear-view "mirror" is a video screen in the dash that

shows the view from a video camera in the rear window. When the car is stopped, the screen functions as the display for a personal computer. Another system, called Dialog (from Renault), includes a video screen to receive TV broadcasts on traffic jams, hotel availability, and weather outlooks. West Germany is testing a similar system, using signals carried by wires in the surface of the road and picked up by special radio monitors in the car.

APPLICATIONS BY GOVERNMENT AGENCIES

Government agencies in general are interested in the use of EVMT technology to collect vehicle data, streamline and enhance the operation of complex regulating processes, enhance highway engineering and design work, and improve traffic flow. The following are some of the initiatives being taken by various organizations.

Weigh-In-Motion (WIM) and Automatic Vehicle Classification (AVC)

Truck weight data have been collected for many years for a wide variety of reasons, such as pavement design, bridge design, size and weight enforcement, legislation and regulation, administration, and planning. Originally, this information was acquired by weighing vehicles statically. However, advances in WIM/AVC technology [38,39] over the past ten years have produced equipment that is effective in measuring the dynamic wheel forces of moving vehicles. There are many WIM/AVC systems used by many states and provincial governments in North America. A typical WIM/AVC system has weighing platforms with an associated electronic roadside monitoring system. Inductive loops are also used in conjunction with the weight sensor to provide information on the presence, speed and length of passing vehicles. Length detection by the inductive loops is also a key component in AVC. Figure 3 shows the WIM and AVC system configuration.

Automatic Vehicle Identification (AVI)

AVI [39,40] devices consist of transponders which are attached to the vehicle and interrogators which read the transponders. AVI devices have been used for several years to track and identify boxcars for railroads and identify buses at toll bridges. Experiments with AVI devices have been carried out to track transit buses. AVI devices can be very useful to highway and regulatory agencies for tracking the transport of hazardous materials, studying commodity flows, and identifying overweight and illegal vehicles in conjunction with WIM equipment.

Heavy Vehicle Electronic Licence Plate (HELP) System

Eight US western states and British Columbia have recently joined together to examine the practicality of utilizing a

combination of WIM and AVI technologies over a highway network spanning several states and provinces. This project, called the Crescent Demonstration Project, is to demonstrate the utility of an integrated electronic heavy-vehicle monitoring system [41,42]. Trucks and heavy vehicles are equipped with AVI transponders; and WIM/AVC stations at certain highway sites will collect vehicle-identification data from the AVI transponders on passing vehicles. These data will be matched with information on loads and lengths from road sensors to provide a profile of each vehicle. The collected information can be sent via phone lines or satellite to government regulatory offices and to fleet terminals. The AVI transponder aspect of the project requires significant co-operation from trucking companies. For the Crescent Demonstration Project, AVI transponders will be mounted on some 10 000 trucks from 200 companies and about 100 monitoring sites will be equipped with WIM/AVI systems. The project is expected to be completed in June 1988. Figure 4 shows the HELP system concept.

There is growing support in Canada and the US for a national weight-distance tax [43,44] on heavy vehicles. Many transportation officials consider this tax the most equitable way to charge heavy vehicles for their use of the highways. However, the difficulty of enforcement and ease of evasion are the concerns most often mentioned by opponents to the tax. Deployment of AVI devices on heavy vehicles is seen as a promising way to decrease evasion of a weight-distance tax. The Crescent Demonstration Project is a test being conducted to facilitate the administration and auditing of weight-distance user fees.

Traffic Management System

There are many computerized traffic management systems [45,46] installed in major urban centres around the world to improve freeway traffic and city area traffic. These systems generally operate in real time to collect and analyze traffic data transmitted from roadway sensors and to control traffic lights at intersections or freeway entrance ramps to improve traffic flow. There is no direct information exchange between vehicles on the roadway network and the traffic management system. Figure 5 shows the traffic management system concept.

Dynamic Route Guidance

The purpose of the dynamic route guidance system [47] is to utilize traffic data collected from roadway network sensors to provide traffic condition and routing information to drivers of vehicles equipped with on-board transponders. Because the roadside equipment required is expensive, implemented route guidance systems are generally experimental and limited to small urban centre areas.

INTER-RELATIONSHIP AMONG DIFFERENT APPLICATIONS BEING CONTEMPLATED

These new vehicle electronics promise to improve performance and safety as well as convenience. With on-board computers in place, it will be much easier to add new functions to a vehicle, and eventually, vehicles will be very closely connected to the outside world. Cellular mobile phones with voice-control systems will enable drivers to dial a number and talk without removing their hands from the wheel. Nationwide satellite navigation and communications systems will allow commercial vehicle drivers to exchange messages with fleet head offices by way of systems such as WAVM. Once mobile communications become common, they will link drivers to a wide variety of outside information.

These same facilities will allow drivers access to roadway network traffic information from various traffic management systems and systems similar to HELP. Before this can happen, government sponsored systems similar to HELP and traffic management systems will have to incorporate functions that access and disseminate roadway information and are based on new mobile communications infrastructures for equipped vehicles. On the other hand, the potential role of the traditional electronic route guidance system which relies on roadside equipment and special vehicle on-board equipment may be diminished in importance.

In the area of commercial vehicles, government agencies are evaluating and testing ground-based heavy vehicle monitoring systems such as HELP for such applications as tax reporting, streamlining complex federal and provincial regulatory processes, statistical vehicle data collection, and enhancing highway engineering and design work. On the other hand, the transportation industry is pursuing satellite-based vehicle monitoring systems such as WAVM for fleet management and improvement of vehicle dispatch and productivity. Two studies [43,44] point out that a ground-based heavy vehicle monitoring system can only provide fixed point checks for vehicle weight, while a satellite-based vehicle monitoring system incorporating on-board vehicle weighing technology offers direct and continuous measurement of axle weight times distance. If these two types of heavy vehicle monitoring systems can be designed to exchange information that can satisfy both sides' needs, then the government sponsored systems similar to HELP may be simplified and their total cost reduced. The WAVM type systems as pursued by the transportation industry will also derive more benefits from this exchange of information.

CONCLUSIONS: INTEGRATED EVMT SYSTEMS FOR FUTURE APPLICATIONS

While the transportation industry is pursuing the use of EVMT technology to improve fleet management, vehicle dispatch and

productivity, government agencies are testing a plan to use the technology to collect vehicle data, streamline complex regulatory processes, enhance highway engineering and design work, and improve traffic flow. Given these diversified efforts being pursued by different interested parties, one can assume that different types of EVMT systems will be implemented by government agencies and the transportation industry for their own use in the future. Under these circumstances, interfaces among various new EVMT systems have to be developed in order to derive more benefits from newly implemented systems. For example, a national WIM/AVI system can provide an infrastructure for interface between the vehicle/carrier and the regulatory government agency. A WAVM system and the fleets' management information systems can be linked with WIM/AVI systems to exchange information that will be help to satisfy complex federal and provincial regulation procedures and requirements. A commercial EVMT system such as WAVM can also be linked with traffic management systems in major corridor and urban centre areas to obtain important route traffic information and to facilitate just-in-time transport control, dispatch and routing control. Figure 6 shows the concept of interface among public and private EVMT systems.

When these interfaces among various EVMT systems -- those already installed and those in the study stage -- are developed and implemented, a synergy from these various EVMT systems will develop and will contribute to greater efficiency and productivity of highway infrastructure and transportation fleets.

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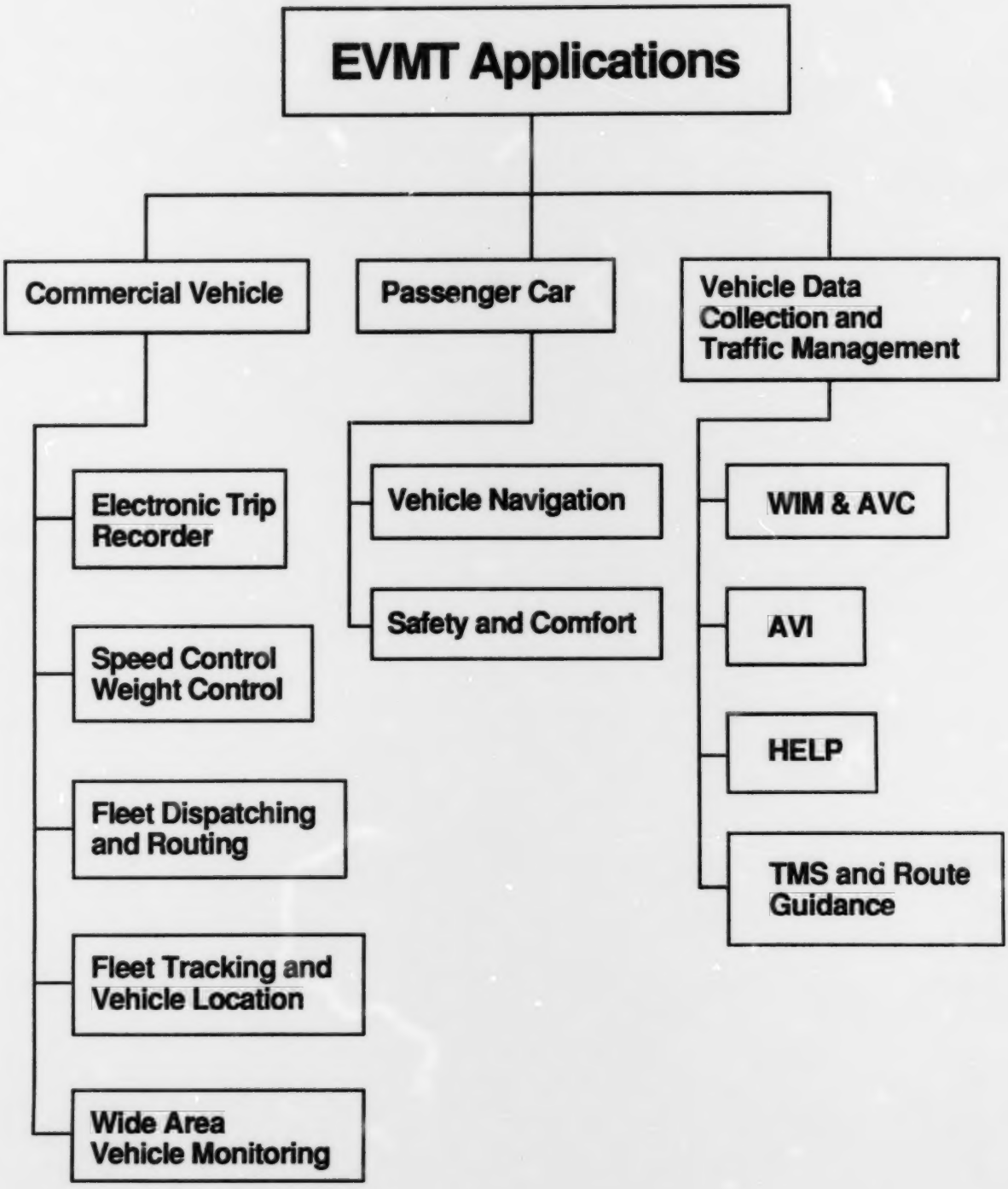

Figure 1/ Electronic Vehicle Monitoring Technology Application Areas

Wide Area Vehicle Monitoring (WAVM)

- Wide area coverage from coast to coast
- Satellite-based vehicle navigation and communications
- Interim WAVM under development
- Computerized system capable of linking with other EVMT systems
- Long-haul and regional trucking operation

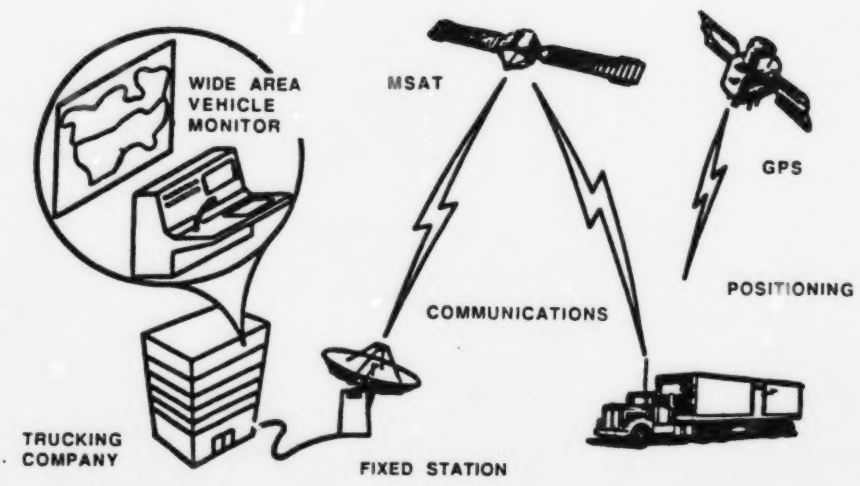

Figure 2/ WAVM System Configuration

Weigh-In-Motion (WIM) and Automatic Vehicle Classification (AVC)

- Weighing platform
- Electronic roadside monitoring system
- Inductive loop
- Speed, vehicle classification, and load

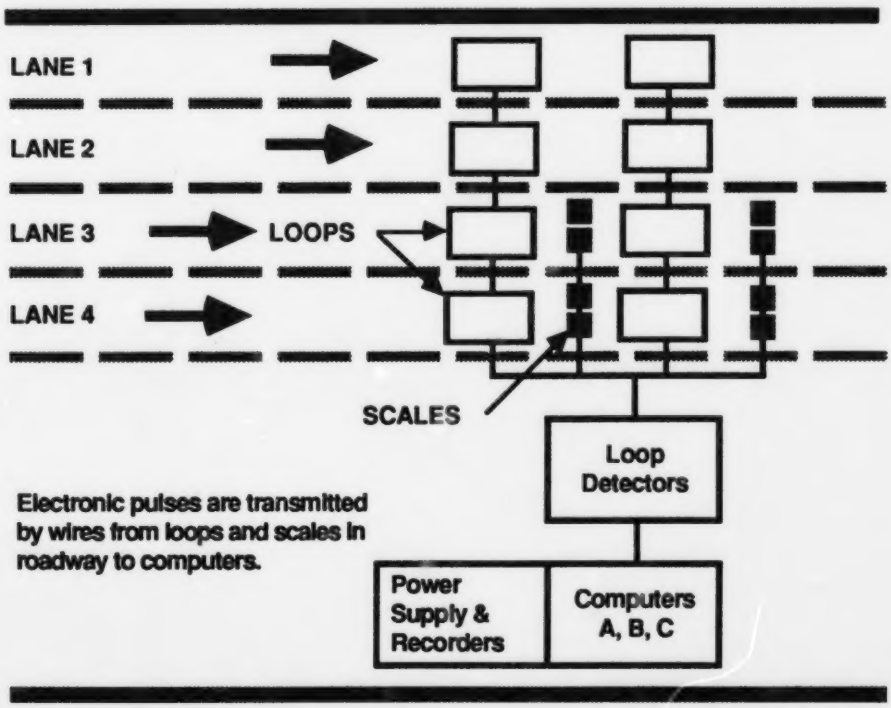

Figure 3/ WIM and AVC System Configuration

Heavy Vehicle Electronic Licence Plate (HELP) System

- WIM and AVC stations
- AVI transponders
- Vehicle identification
- Load and vehicle classification
- Roadway-based

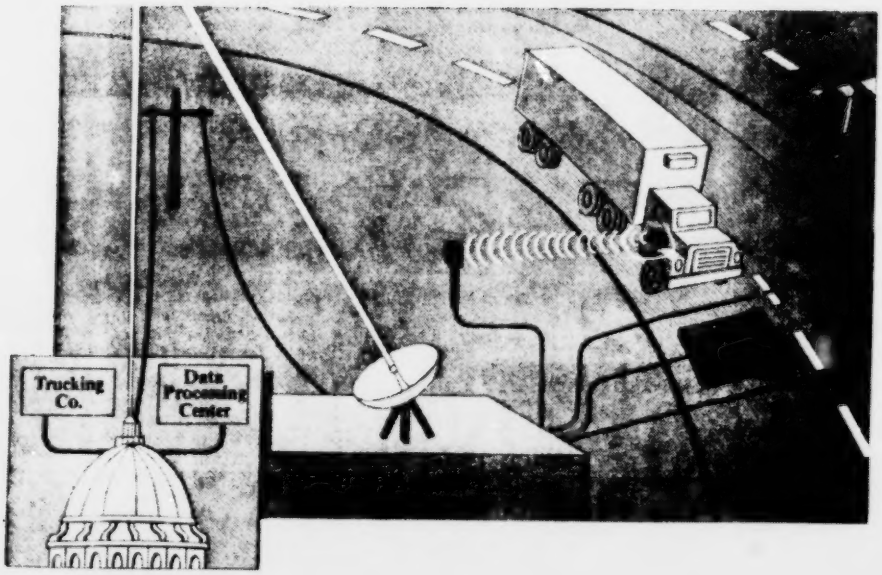

Figure 4/ HELP System Concept

Traffic Management Systems

- Roadway sensors to collect and analyze traffic
- Control traffic lights and signs
- Area network and freeway corridor
- No direct information exchange with individual vehicles

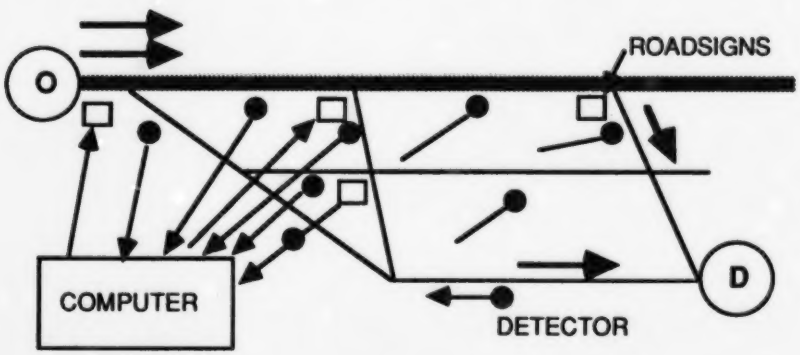

Figure 5/ Traffic Management System Concept

Interface Among EVMT Systems

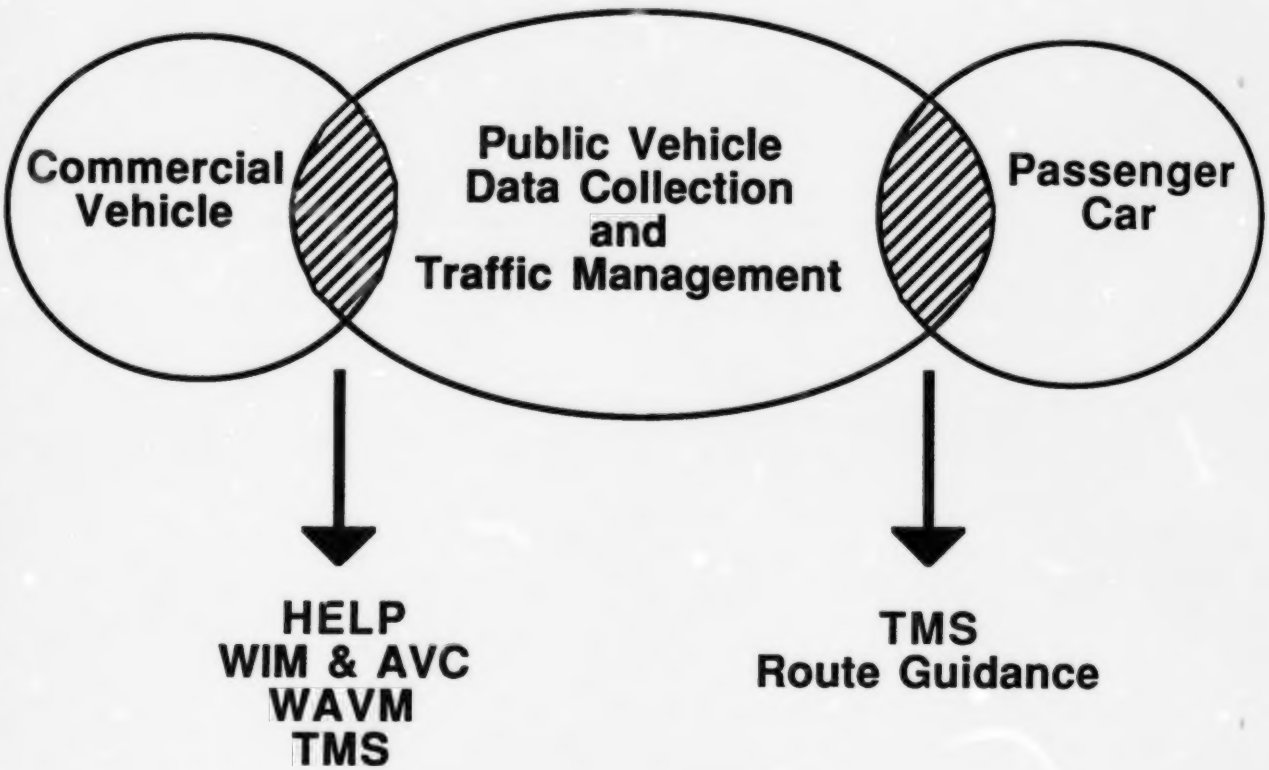

Figure 6/ Interface Among Public and Private EVMT Systems